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GUSTATORY SWEATING WITH SPECIAL REFERENCES TO ITS MECHANISM*

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It has been known that gustatory sweating appears not infrequently as a sequel to injury or operation of the parotid region and to the cervical or thoracic sympathectomy, and is produced by ingestion of certain kinds of foods, commonly of spicy or sour taste. Various explanations have been offered for this phenomenon, but its mechanism still remains to be clarified. This paper deals with a case of gustatory sweating which appeared in association with the development of subclavian aneurysm.

CASE REPORT

A 43-year-old coal-miner was admitted to the hospital on March 20th, 1965 with general malaise and anorexia.

Twenty-four years ago, when he was nineteen years old, the right lower neck of the patient was stuck with a knife by his comrade. According to the protocol of a surgeon who treated his wound at that time, the wound was located immediately above the right clavicula and 5 cm lateral to the right sternoclavicular joint; the wound was stitched primarily, without any ligation of blood vessels, and healed uneventfully. Five years later, he was told by a physician that his heart had a murmur, but he experienced neither shortness of breathing, palpitation nor peripheral edema. And two years later, there was a diagnosis of hypertension. The following year he was admitted to the hospital with palpitation, shortness of breathing and edematous swelling of the eye lids. At that time, the blood pressure was 130/80 and his urine protein was moderately positive. His urine became protein-free in a few days. He was discharged from the hospital on the 12th day of hospitalization, and he began to work as hard as before. Meanwhile he noticed that no sweating occurred on the right side of his face in the summer season and in a hot environment such as in the underground pit.

Early in February 1965, he felt general malaise, weakness, nausea and dull pain in the epigastric region. A few days later his face became slightly edematous and he visited the clinic. His blood pressure was 170/100 and there was a moderate amount of urine protein. He received ambulatory treatment of glomerulonephritis. A week later the blood pressure became 130/70, but only a slight amount of urine protein was present; and at the end of February his urine became protein-free. However, he complained of nausea, vomiting, feeling of stenosis at the pharynx and discomfort in the retrosternal region. His appetite diminished gradually and he could not take any food other than tart food such as Japanese grapefruits, which gave him a refreshed feeling. He took two or three grapefruits a day; and noticed sweating on the right cheek and the right side of the neck while eating grapefruit. He was admitted to the hospital on the 20th of March.

Physical Examination

His right upper eye lid was ptotic, and the right eye was enophthalmic and miotic. A scar, 5 cm long, was found in the region of the right clavicula. Pulsation and vivid thrill were felt in an oval area (6 cm × 5 cm) close to the scar. The long axis of the area ran downwards from lateral to medial. The area extended to the most medial part of the right supraclavicular region. Systolic murmur was also heard in this area. No râles were audible in the lungs; the heart was normal. No mass nor tenderness was felt in his abdomen. Neurologic examination revealed no abnormal sensations and reflexes in his upper and lower extremities. There was no peripheral edema. Laboratory examinations for blood cells, serum electrolytes, serum proteins and urine, and the function test of the liver were all normal except for urine protein. The urine became protein-free on the 14th day of hospitalization. The serum Wassermann reaction was negative.

Physical examination revealed that the patient has a post-traumatic aneurysm which arises from the proximal portion of the right subclavian artery and that the appearance of the Horner's syndrome on the right side might be associated with the growth of the aneurysm.

OBSERVATIONS

In this patient, observation of sweating was made by the iodine-starch method of Wada and Takagaki (1, 2)†. The skin was painted with 2 to 3% solution of iodine in absolute alcohol and when dried, it was covered with a mixture of corn starch powder and castor oil (about 1:1 in volume). Sweating was visualized as black spots at the orifices of the sweat ducts.

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1. Regional disturbance in thermoregulatory sweating.—The sweating test was carried out at room temperatures between 34° C and 39° C. In order to promote sweating, the patient was allowed to take three cups of hot water. It was found that thermoregulatory sweating was almost completely abolished on the right half of the face, neck and the upper part of the frontal chest, the right shoulder and the lateral side of the right upper limb. The corresponding areas on the left side showed almost normal thermoregulatory sweating. It was noticed that sweating was most vigorous in the area closely adjacent to the nonsweating area, especially on the frontal chest. This reminded us of perilesional hyperhidrosis. On the forehead, neck and frontal chest, the areas of thermal sweating were sharply demarcated by the median line of the body.

2. Sweat response to gustatory stimulus.—As gustatory stimulus, grapefruits were used, because the patient had no appetite except for grapefruits for about one month. The observation was made at room temperature of about 11° C.

Immediately after merely looking at a grapefruit, the patient rapidly exhibited a definite sweat response in the right supraclavicular region, while the corresponding region on the left side showed no sweating. The black spots produced by sweating were removed by wiping with a piece of cotton moistened with absolute alcohol, and the procedures for visualizing sweat were performed again. These procedures were repeated until the sweat response ceased.

On taking a grapefruit in his mouth, the patient developed sweat response on the right side of the face, neck and the upper part of the frontal chest, the right shoulder and the lateral side of the right upper limb within a minute, as illustrated in Figures 1 and 2. These areas coincided, though not exactly, with those which were devoid of sweat response to heat. On the face, neck and chest the areas of gustatory sweating were marked off almost sharply in the median line of the body. But on the right arm, the area of gustatory sweating overlapped, though for only a short distance, the area of thermal sweating. With the occurrence of the gustatory sweating, the patient noted a sensation of warmth on the right side of the face, but without any definite flushing in this area. It was found that the area of gustatory sweating extended downwards so as to include the dermatome of the right seventh cervical spinal nerve.

At the same time, sweating was seen also on the palm of the right hand. The latter may have been

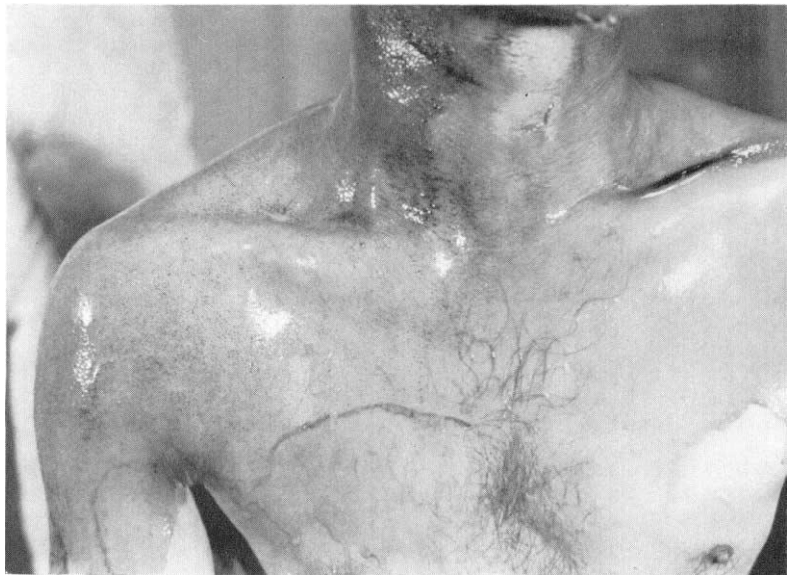

FIG. 1. Gustatory sweating produced by eating a grapefruit. Sweating was visualized by the method of Wada and Takagaki. The lower border of sweating on the right side of the frontal chest and the medial border on the right upper arm are indicated by black lines. The black stains on the left side of the neck are not caused by sweating. Photographed 10 minutes after ingestion. Reduced to ¼. Not retouched.

of emotional origin, since there was no significant difference between the palms of both hands in the pattern and magnitude of sweating. It may be added that gustatory sweating on the right shoulder continued, though gradually diminished, for more than 10 minutes after elimination of the tart taste which had remained in the mouth for about 20 minutes after ingestion.

3. Local sweat responses to some sudrific drugs. —As test agents, acetylcholine chloride, L-adrenaline hydrochloride and nicotine were used. Each test agent was dissolved in or diluted with 0.9% NaCl solution, and 0.1 ml each of the test solutions was injected intradermally using a tuberculin syringe. The test was performed on both sides of the upper part of the frontal chest. The room temperature and the relative humidity during the test were 20° C and 50%, respectively.

Acetylcholine: The effect of acetylcholine in graded concentrations of 10^{-7} to 10^{-5} was examined. The effective concentration of acetylcholine was found to be 10^{-7} on the right side, while no definite response was seen on the left side even with 10^{-5}. An impression was gained that the sensitivity of the sweat glands to acetylcholine was somewhat higher in the area of gustatory sweating than in the corresponding area of the left side.

Adrenaline: The effect of 10^{-5} to 10^{-4} adrenaline was tested, but no sweat response was observed on the upper chest of both sides at these concentrations, indicating that the excitability of the sweat glands in the patient was low, as compared with that in healthy adults (2).

Nicotine: After 10^{-5} nicotine was intradermally injected on the right and left sides, the axon reflex sweating became visible 75 seconds and 115 seconds, respectively, after the start of injection, and spread over an oval area, disposed longitudinally in a transverse direction; the maximum sweating areas were measured with a planimeter to be 7.5 cm^2 and 6.0 cm^2, respectively. These differences might be due to the difference in the excitability of the sweat glands between these two areas.

The effect of grapefruits on the skin temperature of the forehead, cheek and supraclavicular region and on the width of the pupils was examined, but no changes were noted.

The Horner's syndrome on the right side and the failure of thermal sweating on the right half of the face, neck and the upper region of the frontal chest, the right shoulder and the lateral side of the right upper limb suggested that the right cervical sympathetic chain might be blocked by the aneurysm of the right subclavian artery.

FIG. 2. Close-up of gustatory sweating on the lateral side of the right shoulder and the right side of the frontal chest. Photographed 10 minutes after ingestion of a grapefruit. Reduced to ½. Not retouched.

Furthermore, the fact that gustatory sweating was localized to these limited areas led us to assume that the right cervical sympathetic chain might be connected with the vagal fibers at about the level at which the blockade had occurred.

DISCUSSION

The present case report deals with the gustatory sweating which developed very likely as a result of lesion of the right cervical sympathetic chain by the subclavian aneurysm. A number of cases of gustatory sweating which appeared after injury or operation of the parotid region have been reported by previous authors largely as auriculotemporal syndrome or Frey's syndrome consisting of sweating and flushing on the face coincident with the distributions of the auriculotemporal nerve.

The appearance of gustatory sweating after operation of the cervical and/or thoracic sym-

pathetic chains has also been described (3–7). According to Haxton (7), gustatory sweating on the face was found in 4 out of 12 cases of cervicothoracic ganglionectomy, and in no fewer than 9 out of 24 cases of upper thoracic sympathotomy. Thus, gustatory sweating after sympathectomy has been reported to be restricted to the face.

Haxton (7), however, noticed that in one case of gustatory sweating following cervicothoracic ganglionectomy, the electrical conductivity of the skin in the cubital region was increased in spite of the fact that no visible sweating was recognized in this region. The most bizarre case reported by Herxheimer (8) was similar to ours in that the gustatory sweating appeared not only on the face, but also on the left side of the neck and the left shoulder and arm. His observation was made by the method of Wada and Takagaki (1, 2) on the patient who had a thoracoplasty on the same side, in which the upper eight ribs were removed for treatment of a pulmonary tuberculosis.

It has been reported that the thermoregulatory sweating fails to occur or is diminished in the area coincident with that of gustatory sweating (4, 6–11). This was also observed in the present case.

It may be noted that in the present case the patient showed gustatory sweating through conditioned reflex, that is, when he merely looked at a grapefruit. Similar findings were reported by List and Peet (6) and by Rappoport (12). However, Freedberg *et al.* (10) noted that in their patient with auriculotemporal syndrome gustatory sweating did not occur in spite of the appearance of psychic salivation.

Several explanations have been proposed for the development of gustatory sweating after the sympathectomy. Guttmann (3) suggested that the occurrence of gustatory sweating reflex after cervical sympathectomy was an evidence of double innervation (sympathetic and parasympathetic) in human sweat glands and concluded that the efferent pathway might be involved in bulbar parasympathetic fibers distributed mainly with the facial nerve.

Wilson (4) also suggested that the sweat glands of the human face might have a double innervation: sympathetic sudomotor fibers and accessory secretory fibers which might arise from the brain stem. Thus, gustatory sweating is produced through the accessory secretory fibers, and is also related to hypersensitivity of denervated sweat glands. However, no definite anatomical or physiological evidence for the existence of such accessory secretory fibers has yet been demonstrated.

List and Peet (6), and Haxton (7) advanced the hypothesis that gustatory sweating is caused by hypersensitivity of denervated sweat glands to acetylcholine liberated from the cholinergic cranial parasympathetic fibers (6) or from the cholinergic sympathetic fibers (7). However, the evidence available indicates that the sensitivity of human sweat glands to acetylcholine is not increased, but rather decreased by their denervation (13–16). And, it can hardly be accepted that acetylcholine diffuses through the tissue to activate the neighboring sweat glands (11).

Gardner and McCubbin (17) proposed the hypothesis that gustatory sweating following sympathectomy might be due to aberrant connections between the sympathetic sweat nerve fibers and the adjacent vagal nerve fibers which were accidentally damaged during sympathectomy.

Murray and Thompson (18) suggested that gustatory sweating following sympathectomy might be due to sprouting of residual sudomotor nerve fibers or of adjacent vagal nerve fibers in response to degeneration of nerve fibers normally innervating the sweat glands. This suggestion was based on their observation that, in cats, the section of pre- or post-ganglionic sympathetic fibers at the superior cervical ganglion is followed by nerve sprouting from neighboring intact fibers, and that the complete preganglionic denervation of the superior cervical ganglion caused the sprouting of vagal efferent fibers (18–20).

Laage-Hellman (11) and Herxheimer (8) supported the view of Murray and Thompson that gustatory sweating following sympathectomy might be a sequel to sprouting of adjacent vagal nerve.

In the present case, the gustatory sweating can also be explained as being the result of re-innervation of the sweat glands by sprouting from adjacent vagal nerve fibers at the level of about the subclavian ansa, as judged from the dermatomes. It can be assumed that the connection might be formed between the preganglionic sympathetic sweat nerve fibers and the preganglionic vagal nerve fibers to the gastro-intestinal tract. This is not unlikely since both nerve fibers are cholinergic in nature and the sweating axon reflex

can be produced in the gustatory sweating area as described above. Thus, the impulses of the vagal efferent nerve fibers in this gustatory sweating reflex would be conveyed to the sweat glands in the involved area by communication with the sympathetic sudomotor fibers by the vagal sprouts.

In the present observation, the width of the pupils, the skin temperature and the pilomotion of the involved area while eating grapefruits were also studied. These showed no response to gustatory stimulus in contrast to the finding of Herxheimer (8) that pilomotion occurred in the involved area in response to gustatory stimulus.

The sweat glands in the area of gustatory sweating have been reported to be hypersensitive to acetylcholine and other parasympathomimetic drugs, as compared with those in unaffected areas (4, 9–11, 17, 21). A similar result was obtained in our observation with intradermal injection of acetylcholine. This finding suggests that the reinnervation through the connection of the sympathetic sweat nerve with the vagal nerve may increase the excitability of the sweat glands involved. But much more evidence is needed to establish this finding as a fact.

Gustatory sweating following lesion of the parotid region might be similarly explained, that is by "sprouting" from adjacent parasympathetic cholinergic secretory fibers.

There have of course been reports of cases of gustatory sweating, probably of central origin, which could not be satisfactorily explained by collateral sprouting in the autonomic nervous system: *e.g.*, Mellinkoff and Mellinkoff (22) reported that their daughter, aged 8 months, exhibited gustatory sweating on her left knee while sucking milk.

SUMMARY

A case of gustatory sweating associated with aneurysm in the right cervical region has been described. Gustatory sweating was observed not only on the right half of the face, but also on the right side of the neck and of the upper part of the frontal chest, on the right shoulder and the lateral side of the right arm.

Thermoregulatory sweating was almost completely abolished in the involved area, but the responsiveness to intradermal acetylcholine of the sweat glands in the affected area was increased. Further, it was found that axon reflex sweating was elicited by intradermal injection of nicotine in the gustatory sweating area.

Gustatory sweating in the present case can possibly be explained by assuming that an aberrant connection was formed by collateral sprouting from the efferent vagal nerve fibers into the preganglionic sympathetic sweat nerve fibers, very probably at about the level of the subclavian ansa.

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